ORIGINAL ARTICLE

Volume 17 Issue 4 2025

DOI: 10.21315/eimj2025.17.4.4

ARTICLE INFO

Submitted: 08-10-2024
Accepted: 28-04-2025
Online: 31-12-2025

Evaluation of an Artificial Intelligence Course Integration into the Undergraduate Medical Curriculum in Egypt: A Mixed-Methods Study

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To cite this article: Elhoshy H, Rashed S, Fouad S, Abouzeid E, Talaat W. Evaluation of an artificial intelligence course integration into the undergraduate medical curriculum in Egypt: a mixed-methods study. Education in Medicine Journal. 2025;17(4):45–64. https://doi.org/10.21315/eimj2025.17.4.4

To link to this article: https://doi.org/10.21315/eimj2025.17.4.4

ABSTRACT

The use of artificial intelligence (AI) in healthcare mandated curricular changes to prepare medical students for the era of AI. Basics of AI design, and the ways of using AI in medical profession should be integrated into the medical curricula. This study aims to describe the design, implementation, and evaluation of an innovative online course on AI for undergraduate medical students. The course was introduced within the new competency-based undergraduate medical programme for third-year undergraduate medical students at Alexandria Faculty of Medicine. A non-probability sample of 244 students was included. Evaluation of the course followed Kirkpatrick's model. For students' reaction (level 1 Kirkpatrick's model), a self-administered questionnaire was used to measure students' perceptions towards course content, technology, instructors, support received, and course assessment using both Likert scale and open-ended questions. For students' learning (level 2 Kirkpatrick's model), quasi-experimental design (pre-test and post-test) was used to evaluate students' learning (level 2). Multiple-choice questions were used for the pre-test and post-test questions. In addition, a focus group was implemented to explore perceptions of the course teaching faculty. About 216 students completed the course evaluation. Over 85% of students gave positive feedback on the course. Students valued the accessibility of instructors (81.3%), the encouragement for discussion (71.9%), the diverse materials used (71.9%), and the support available for course activities (75%). Additionally, there was a statistically significant difference between the mean scores, showing significant improvement in post-test scores compared to baseline scores at the start of the course ($p < 0.05$). Students showed a positive perception towards all aspects of the course, including its design, activities, materials, and instructor availability. The course significantly improved their understanding of AI.

Keywords: *Artificial intelligence, Online learning, Undergraduate medical curriculum, Community of inquiry, Kirkpatrick evaluation*

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INTRODUCTION

Rebooting medical education involves recognising that future medical practice will be a collaborative effort among physicians, healthcare professionals, machines, and patients. Care will be provided in diverse locations with continuous real-time data, delivered by multidisciplinary teams, and reliant on extensive data and artificial intelligence (AI) for patient monitoring. The roles of healthcare team members will be redesigned, and the interface between medicine and machines will need to be skillfully managed as technology increasingly outperforms humans in various tasks (1).

The integration of AI in healthcare necessitates curricular modifications to equip medical students for the AI era, incorporating essential aspects of AI and its applications in the medical field (2). While the clinical applications of AI in medicine have expanded rapidly over the past decade, its inclusion in medical education is a recent development, with studies only beginning to report on the use of AI in this context (3).

AI is the ability of computer systems to perform tasks that would usually require human levels of intelligence (4). AI has a promising role in the progression of the undergraduate medical curriculum to nurture tomorrow's doctors in today's technological era. However, due to the limited number of studies available for analysis, the scope for evaluating the impact of AI remains restricted (5). In Germany, 71.8% of medical schools offer AI courses, usually as electives or extra-curricular activities. In contrast, 85% of Canadian medical students reported a lack of formal AI education in their medical curricula (6).

Although AI is not a new field, recent advancements in AI technologies, particularly those based on machine learning and large language models (LLM), have significantly increased accessibility and ease of use. Applications like ChatGPT by OpenAI exemplify this progress. Therefore, basic competencies in the field of AI are essential to enable physicians to supervise AI systems; however, they are not taught comprehensively in medical training. On the other hand, medical students have expressed their eagerness to acquire competencies in the use of AI in medicine before they graduate from medical school (7).

Recent publications have explored the challenges in instruction regarding AI, including time available in the curriculum and provided recommendations for curricular content (8, 9). Other studies recommend introducing AI as an integral part of the mandatory curriculum at medical school (10).

In Egypt, the integration of AI into medical education faces several challenges. The first major obstacle is the lack of resources and infrastructure. A significant proportion of participants (64.3%) identified insufficient financial resources as a primary barrier to AI implementation. Additionally, 63.1% cited the country's limited technological advancements as another hindrance (11). Furthermore, negative attitudes towards AI present another challenge. Many medical students and professionals hold unfavourable views regarding AI integration. A study involving medical students and house officers reported that 87.4%

had a negative attitude towards incorporating AI into medical education. Another issue is the limited practical use of AI among medical professionals (11). One study found that only 21.7% of participating physicians had prior experience using AI. Similarly, research on medical students and house officers revealed that 76.4% had inadequate perceptions of AI in the medical field. This lack of hands-on experience impedes the effective adoption of AI tools in healthcare (12). Concerns about AI reliability also contribute to hesitancy. A notable percentage of physicians (44.2%) believed that an AI system malfunction posed a greater risk than an incorrect decision made by a physician. A study conducted on medical students in Egypt emphasised the importance of addressing these concerns and apprehensions among medical students and house officers. Lastly, there is apprehension regarding potential job displacement. Some medical students and physicians expressed concerns about AI replacing them in their roles, with a statistically significant difference in opinion scores between those who were worried and those who were not. While this concern is not universal, it remains a contributing factor to the challenges of AI integration in medical practice (12).

Most of the studies describe the application of AI in clinical expertise training and continuing education, through professional training, self-study, or online courses (8, 13). In line, several frameworks have been proposed to integrate AI into medical education effectively, addressing various aspects such as AI literacy, radiology education, digital skills, case-based learning, progressive exposure, healthcare economics, ethics, and machine learning (14–18). Meanwhile, in undergraduate or graduate education, a few studies describe AI's role, such as flipping the classroom and using virtual reality to exercise to improve students' hands-on skills (19, 20).

Introducing an AI course for undergraduate medical students is crucial to address several significant gaps identified in the current medical education landscape. Studies reveal a significant gap in formal AI education within medical curricula. A majority of participants (84.8%) in a study involving medical students and house officers reported never having attended an AI course. The need for enhanced AI education and training in medical curricula has been strongly emphasised (11). Moreover, the absence of formal AI education in medical curricula further exacerbates this issue, as many medical students have never taken an AI-related course. This educational deficiency contributes to both inadequate understanding and skepticism towards AI, highlighting the urgent need for curriculum integration (12).

Building on this pivotal shift and significant gap, this study seeks to introduce one of the early trials to incorporate AI into undergraduate medical curricula in Egypt. Through the design, the study aims to describe the design, implementation, and evaluation of an innovative online course on AI for undergraduate medical students.

METHODS

Overview

In 2018, Alexandria Faculty of Medicine transitioned to a Competency-Based Medical Education (CBME) model for its five-year undergraduate medical programme. The curriculum was restructured to include 19 integrated system-based blocks during the first 2.5 academic years, spanning six semesters in the pre-clerkship phase. This was followed by clinical sciences training in the remaining six semesters. As part of the curriculum, students were offered the opportunity to enroll in elective courses twice: once in the third year and again in the fifth year of medical school.

In response to emerging demands for curricular innovation and the growing emphasis on AI in healthcare, the faculty introduced an elective AI course for third-year medical students. This initiative aligned with the transition into the clinical phase of training, ensuring that students were simultaneously gaining hands-on experience in patient care, diagnosis, and treatment. To facilitate this integration, an educational project was conceptualised and implemented to design and deliver the AI course.

This research project was structured as an Extended Functional Practical Exam (EFPE), a novel postgraduate assessment method developed to address the limitations of traditional oral or viva examinations. Conducted as part of the doctoral requirements in Medical Education at the Faculty of Medicine, Suez Canal University, the EFPE comprises three distinct phases: educational project planning, implementation, and evaluation (21).

Study Design

This study utilised a quasi-experimental pre-test and post-test mixed-methods design, adopting a pragmatic approach to evaluate students' perceptions of the course as a learning experience and determine whether their knowledge and skills in AI improved following course completion. The integration of quantitative pre-test and post-test data with qualitative methods provided a comprehensive assessment and enhanced the validity of the findings. Participation was entirely voluntary, with confidentiality and anonymity. Students were fully informed of the study's objectives and provided consent for their data to be used for research purposes.

Participants

Due to the elective nature of the course, a non-probability sampling technique was employed, whereby all enrolled students were invited to participate voluntarily. Following verbally informed consent, all course participants agreed to share data for research purposes. In total, 244 third-year medical students completed the course, with 96 students in Autumn 2022, representing 5.8% of the total 1,648 third-year students, and 148 students in Autumn 2023, representing 5.7% of the total 2,587 third-year students. To assess the practical significance of the findings, Cohen's d effect size was calculated using G*Power software (University of Düsseldorf). The analysis, based on a pre-test and post-test design with a one-sample *t*-test (two-tailed, $\alpha = 0.05$, power = 0.80), yielded an effect size of 0.18, indicating a small effect size. Four teaching faculty members of the Medical Education Department were involved in implementing the AI course (two professors and two teaching assistants) and participated in this study.

Procedures

The study procedures included course design, implementation and evaluation. The course design and implementation were informed by the Community of Inquiry (COI), which is a practical framework used for developing effective interactive virtual courses in medical education through assuring the interplay of three pillars: social presence, cognitive presence and teaching presence (22). The course evaluation was based on Kirkpatrick's

Model for Educational Programmes, encompassing two levels of assessments (23). At Level 1 (reaction), students' perceptions of the course were measured through an end-of-course questionnaire developed by the research team. This questionnaire contained 16 positively framed items assessing five key domains: course content (6 items), technology (2 items), instructors (4 items), support received (2 items), and assessment methods (2 items). A 4-point Likert scale was used to minimise midpoint bias and align with the response patterns of younger participants (24). The questionnaire was guided by a sustainable evaluation framework for online learning and demonstrated strong reliability, with a Cronbach's alpha of 0.89. Additionally, two open-ended questions were included to capture qualitative feedback on course advantages and areas for improvement. To ensure validity, two medical education experts reviewed the questionnaire for clarity, comprehensiveness, relevance, and appropriateness. Their feedback led to refinements that enhanced clarity and eliminated redundancy.

At Level 2 (learning), students' cognitive skills were assessed using a 15-item multiple-choice question (MCQ) test designed to evaluate their knowledge acquisition. Developed by the course teaching assistant and reviewed by two professors, the test was administered twice—once as a pre-test before the course and again as a post-test after completion—to measure knowledge gains.

To complement these assessments and enhance data triangulation, a focus group discussion was conducted with all four course instructors. This session followed a structured protocol and centred on two main questions: what were the course strengths? and what recommendations could improve it? The discussion was recorded, and key themes were summarised. Data saturation was reached, as no new themes emerged, ensuring a comprehensive exploration of the course impact from an instructional perspective.

Data Analysis

Data from the course evaluation questionnaires were coded. As regards the pre-test and post-test, they scored out of 15. Quantitative data from questionnaires and test scores were then entered and analysed using the IBM Statistical Package for Social Sciences (SPSS version 22.0, Armonk, NY: IBM Corp.). Descriptive statistics were used (percentages, mean, and standard deviation). Paired sample *t*-test was used to compare the results before and after the course. P-value < 0.05 is considered significant.

Qualitative data from open ended questions and focus group were analysed thematically. Thematic analysis followed the scientific steps of thematic analysis process: familiarisation with data, generating initial codes, searching for themes, reviewing themes, and final reporting of themes (25). To ensure rigour and consistency, a structured coding framework was developed using spreadsheets, where data excerpts were coded manually based on recurring patterns and conceptual relevance. Manual coding of the data allowed for a nuanced, interpretative approach to the data, ensuring that contextual meanings were preserved.

RESULTS

Course Design

A 12-day online elective course was designed to provide foundational knowledge and skills in AI, focusing on its applications in the medical profession and the evolving role of physicians in the AI era. The course was developed in alignment with the National Authority for Quality Assurance and Accreditation of Education (NAAQAE) Egyptian medical graduates' competency framework to ensure that graduates acquire essential competencies relevant to AI in healthcare (26). To achieve its objectives, the course was structured into three modules: AI and the Medical Profession, which introduced AI applications in healthcare; Basics of AI Systems, which covered fundamental AI concepts and functions; and Using AI in Patient Care, which explored practical applications of AI in diagnosis and treatment.

The course was offered to third-year medical students at Alexandria Faculty of Medicine and was introduced during the clinical clerkship phase of the five-year undergraduate medical programme. It was conducted four times each in Autumn 2022 and Autumn 2023.

Course Development and Quality Assurance

The course development team included three professors and one teaching assistant, all of whom were medical education experts holding either a diploma or a master's degree in medical education. The course syllabus and materials were developed by an assistant lecturer in the Medical Education Department. The course designers conducted a thorough literature review to ensure that the content was well-grounded in evidence-based practices and optimised for healthcare applications (2, 27–29). Although the instructors did not have specialised expertise in AI, the module topics were carefully tailored to align with medical contexts, ensuring their relevance to students' future clinical practice. To further support learning, a diverse selection of open-source videos covering fundamental AI concepts was provided. For highly specialised AI topics beyond the instructors' expertise, these external resources were strategically integrated, ensuring comprehensive and accurate coverage of advanced concepts while maintaining the course's overall instructional quality.

To ensure content quality and rigour, the course underwent a multi-level review process. Internal review was conducted by the Bachelor of Medicine and Surgery (MBBCh) programme director and the head of the Medical Education Department at Alexandria Faculty of Medicine, while external review was carried out by the head of the Medical Education Department at the Faculty of Medicine, Suez Canal University. Based on recommendations from medical education experts, several enhancements were implemented to optimise the course for online learning. These improvements included incorporating additional video resources to enrich content delivery, developing a teacher's guide to standardise instructor training, and establishing WhatsApp groups to facilitate communication and student engagement.

The course followed a structured quality assurance framework at two levels. The first level focused on ensuring the quality of online teaching and learning activities, while the second level addressed the management and implementation of the course. To foster interactive learning, the course was designed based on the COI framework, which emphasises social presence, cognitive presence, and teacher presence (22). This framework encouraged collaborative learning through a variety of interactive activities, including group research projects, debates, traditional mini-lectures, and synchronous small-group discussions. Student performance was closely monitored, and individualised feedback was provided based on the type of assignment. A detailed daily course schedule, outlining activities, COI elements, and technology use, is available in Appendix A.

Course Delivery and Learning Platforms

The course was delivered using multiple technology platforms, with Moodle serving as the primary course management system (CMS). As the official online learning platform of Alexandria Faculty of Medicine, Moodle facilitated course management, content delivery, communication, collaboration, and assessment. Additionally, WhatsApp and Zoom were used to enhance interaction and engagement among students and instructors.

Assessment and Grading

The course employed a cumulative grading system with a 60% passing threshold, ensuring continuous assessment rather than a single high-stakes final exam. The grading structure was designed to distribute weight across multiple components, ensuring a balanced evaluation of students' learning progress. Participation in Module 1 synchronous workshops accounted for 15% of the final grade. The largest portion of the grade, 50%, was allocated to debate preparation, presentation, and post-debate reflection, emphasising students' ability to engage in critical discussions and apply their learning. The Module 2 quiz contributed 15% to the final score, followed by the final course exam, which also accounted for 15%. Lastly, 5% of the grade was derived from the post-course evaluation, allowing for reflection on learning experiences and course effectiveness.

This integrated assessment model, similar to the integrated cumulative grade point average (iCGPA) system, provided continuous feedback, which motivated students to remain actively engaged in their learning (30). At the course management and implementation level, Moodle course development adhered to Quality Matters (QM) higher education course design rubric, ensuring compliance with key quality standards (31). These standards covered various domains, including general course information, course goals and learning outcomes, assessment strategies, course materials, learner engagement, course technology and learner support. A detailed mapping of online teaching practices to these quality standards is available in Appendix B.

Challenges and Instructor Preparation

One of the primary challenges in course implementation was the limited availability of AI experts in healthcare. To address this challenge, faculty members from the Medical Education Department at Alexandria Faculty of Medicine were selected to design and lead the course. The instructional team, consisting of two professors and two teaching assistants, was responsible for delivering synchronous online sessions, evaluating assignments, offering constructive feedback, maintaining communication with students, and overseeing course grading and reporting. Although the instructors lacked specialised expertise in AI, the course instructors adhered to the carefully structured design, ensuring that the content remained relevant to healthcare applications while effectively integrating AI concepts. To ensure effective course delivery, all instructors underwent pre-course training, which covered essential topics such as online teaching strategies, course content, activities and assessment methods. In addition, they reviewed all course materials and received a detailed teacher's guide to support synchronous lesson planning. This preparation ensured that instructors were well-equipped to deliver the course effectively, engage students in interactive learning, and maintain high educational standards.

Course Evaluation

Out of the eight course iterations, 244 third-year medical students enrolled, with an average of 30 students per iteration. All participants passed the end-of-course exam and completed the course successfully.

The comparison between synchronous and asynchronous activities reveals notable differences in student engagement and submission patterns. Synchronous activities, such as live sessions, exhibited variable attendance rates, with lower participation in the course orientation and Module 1 workshop (66.7%) compared to the Module 1 debate session (94.2%), suggesting that interactive and discussion-based activities may encourage higher engagement.

In contrast, asynchronous activities demonstrated higher overall participation and timely submission rates, particularly for structured assessments such as the Post-Debate Reflection (94.2%), Module 2 Quiz (97.2%), and course post-test (97.2%). However, more complex tasks requiring independent research, such as the AI debate assignment, had a lower on-time submission rate (75%), indicating that students may require additional time and support for extensive, research-based activities.

For Kirkpatrick level one, 216 out of 244 students took the final course evaluation questionnaire with a response rate of 88.5%. More than 85% provided positive feedback (agreed and strongly agreed) regarding all course aspects as shown in Table 1. Satisfaction was categorised according to mean score into low satisfaction (1.00–1.99), intermediate satisfaction (2.00–2.99), and high satisfaction (3.00–4.00), as shown in Table 1. It is noteworthy that all items received a high satisfaction mean score.

Table 1: Students' perceptions towards the course

Domains/Items	Mean ± SD	1 Strongly disagree (%)	2 Disagree (%)	3 Agree (%)	4 Strongly agree (%)	Satisfaction category
The course used different types of activities: discussions/case studies/ lectures	3.44 ± 0.504	0.0	0.0	56.3	43.7	High
The course activities were engaging	3.44 ± 0.564	0.0	3.1	50.0	46.9	High
The course instructions were clear	3.25 ± 0.672	0.0	12.5%	50.0	37.5	High
The course topics were interesting	3.75 ± 0.440	0.0	0.0	46.9	53.1	High
Support was available to explain course activities	3.44 ± 0.669	0.0	0	25.0	75.0	High
It was easy to use Moodle	3.31 ± 0.644	0.0	0.0	33.3	66.7	High

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Table 1: (*Continued*)

Domains/Items	Mean ± SD	1 Strongly disagree (%)	2 Disagree (%)	3 Agree (%)	4 Strongly agree (%)	Satisfaction category
Assessment plan was clear	3.34 ± 0.602	0.0	9.4	50.0	0.6	High
Assignments reflect what was taught in the course	3.44 ± 0.564	0	6.3	53.1	40.6	High
Feedback was provided about my assignments	3.38 ± 0.660	0.0	3.1	50.0	46.9	High
I enjoyed course activities	3.53 ± 0.718	0.0	9.3	43.8	46.9	High
The course materials were easily accessible	3.62 ± 0.707	3.1	3.1	31.3	62.5	High
Different types of materials were used lectures videos scientific articles	3.66 ± 0.563	3.1	3.1	21.9	71.9	High
The instructor encouraged discussion	3.50 ± 0.803	3.1	0.0	25.0	71.9	High
The instructor answered questions	3.47 ± 0.803	6.3	0.0	31.2	62.5	High
The instructor provided feedback	3.47 ± 0.842	6.3	3.1	28.1	62.5	High
The instructor was accessible	3.69 ± 0.780	6.3	0.0	12.4	81.3	High

Table 2 highlights the key advantages of the course as described by students in the open-ended questions, with a strong emphasis on activity-related benefits. Most students recognised the value of interactive learning experiences (94.4%), particularly debates (37.5%), and teamwork-driven communication (34.2%). These findings suggest that incorporating diverse and engaging activities fosters active participation and collaborative learning. Additionally, 25% of students acknowledged the instructor's role in providing support, feedback, and effective communication, reinforcing the importance of teacher presence in online education. Furthermore, 15.7% of students appreciated the novelty and relevance of the topic, indicating that exposure to AI in healthcare was both engaging and intellectually stimulating.

Table 2: Students' perceptions of course advantages

Advantages	Frequency, n = 216 (%)	Quotations
Activities related advantages:	204 (94.4)	The activities were so good. I enjoy assignments and debates everything! It was all good. I learned how to work in group. Spirit of participation.
The debate is interesting	81 (37.5)	
The interaction and communication and teamwork	74 (34.2)	
Using multiple types of activities	40 (18.5)	
Discussions	40 (18.5)	

(*Continued on next page*)

Table 2: (*Continued*)

Advantages	Frequency, n = 216 (%)	Quotations
Instructor related advantages: Support Feedback Help received from instructors Easy communication	54 (25.0)	When I took feedback for what I did it was so cool thank you for making us take this journey of research.
Topic-related advantages: The new interesting nature of the topic	34 (15.7)	New knowledge about a field which for the first time I got to research about.

The student recommendations for course improvement, as summarised in Table 3, highlight key areas for enhancing the learning experience. Activity-related suggestions were the most common, with 50% of students emphasising the need for more time for assignments, additional video resources, and increased hands-on practice with AI concepts. These findings indicate that while students valued interactive activities, they desired more opportunities for engagement and deeper exploration of AI applications. Additionally, 12.5% of students recommended integrating mobile applications such as Moodle from the beginning of the course to enhance accessibility and ease of use. Another 9.2% suggested new activities, including inviting international speakers and conducting an in-depth study of a single AI model used in the medical profession.

Table 3: Students' recommendations for course improvement

Recommendations	Frequency, n = 216 (%)	Quotations
Activities related recommendations:	108 (50.0)	Project and assignment need more time. More videos will be useful. It's best to make more interaction and practice.
More time for activities and assignments	40 (18.5)	
More videos	20 (9.2)	
More practice of AI basics	27 (12.5)	
Technology related recommendations: Using the mobile application from the beginning of the course	27 (12.5)	Using Moodle Mobile App from the beginning is much easier.
New activities recommendations: Invite international speakers Study in depth a single model of AI used within the medical profession	20 (9.2)	I think it would be better if we took a single AI model that already applied to medical field and explore it in detail.

Regarding measuring students' performance for evaluating Kirkpatrick's level two, pre-test scores ranged from 5 to 10, with a mean of 6.92 ± 1.61, while post-test scores ranged from 5 to 15, with a mean of 10.22 ± 2.45 (Table 4). A statistically significant difference was observed between the pre-test and post-test mean scores, indicating a substantial improvement in students' knowledge following course completion ($p < 0.05$).

Table 4: Comparing students' performance on the pre-test and post-test

Course	Pre-test mean ± SD (out of 15) (n = 163)	Post-test mean ± SD (out of 15) (n = 237)	*p*-value
AI course mean scores	6.92 ± 1.61	10.22 ± .45	0.000*

Note: * $p < 0.05$

Perception of the Staff Members Regarding the Course

Four teaching faculty members of the Medical Education Department were involved in the implementation of the AI course (two professors and two teaching assistants), and participated in a focus group discussion. The focus group findings highlighted several strengths of the course. Under the theme of course content, students expressed a strong interest in the subject matter and particularly appreciated the debate activities, which they found engaging and thought-provoking. They also valued the opportunity to develop research skills as part of the learning experience. From a technological perspective, students noted that the online format effectively eliminated physical space limitations, offering a more flexible and accessible learning environment. The course instructors also provided recommendations for course improvement. To enhance student engagement, they suggested implementing strategies to ensure all students actively contribute to group assignments. Regarding course activities, they recommended providing clearer guidelines for debate sessions, particularly outlining participation rules. Additionally, they suggested refining the post-debate reflection activity by incorporating a structured scale or closed-ended questions alongside the existing open-ended format, allowing for more systematic and measurable feedback.

DISCUSSION

This study aimed to describe the design, implementation, and evaluation of an innovative online course on AI for undergraduate medical students. In the study results, the students showed positive perception towards the course content, activities, scientific materials, and instructors. These perceptions could be attributed to the students' recognition of the critical role AI plays in healthcare, along with their enthusiasm to acquire AI competencies early in their medical training, as observed by Mehta et al. (7).

This study finding aligns with several other studies that have highlighted the importance of AI in healthcare systems from the perspective of medical students (32). A study conducted by Cho et al. (33) similarly found that most of their students agreed that AI education is necessary in medical school curricula specifically in practical application of AI in medicine, followed by medical ethics of AI, AI theory and AI programming. On the other hand, a study by Khater et al. (34) at Ain Shams University in Egypt found that most medical students had conflicting opinions about the role of AI in medicine and medical education. This discrepancy suggests that while some students are eager to embrace AI, others may have reservations, reflecting a broader range of attitudes towards the integration of AI in the medical field.

In addition, discrepancy was discussed in the study by Khater et al. (34), where students emphasised the importance of incorporating AI teaching into medical curricula. However, they disagreed with the notion that AI would replace human medical professionals, even as they acknowledged AI's potential to improve patient outcomes. Additionally, the students expressed concerns about the ethical implications of AI use in medical education. This highlights a complex view of AI, where students recognise its benefits but are cautious about its broader impact. These concerns also resonate with our study results. Both students and staff members in our study highlighted several challenges in introducing AI into medical curricula. They identified the need for careful planning of both curricular and extracurricular learning opportunities to address AI's clinical usage, ethical issues, and technical limitations. Additionally, they pointed out that training future students and physicians is a significant challenge, particularly in ensuring they are well-prepared to navigate the complexities of AI in healthcare. The availability of resources was also recognised as a major challenge in effectively integrating AI into medical education. This is matching of the inquiries of McCoy et al. (29) who examined what should medical students be taught in the era of AI. Castagno and Khalifa (35) also raised some concerns in their research regarding patient safety and quality of care delivery with the importance of finding the best approaches to integrate AI tools in clinical practice (27).

The results of our study also revealed a significant improvement in students' knowledge between the pre-test and post-test. This increase could be partially attributed to the students' perceptions of AI's importance in healthcare, as well as the course design, which was informed by the COI framework and supported by rigorous quality planning during course development and implementation. The online format, along with the combination of diverse materials, including lectures, videos, and scientific articles and practical assignments, likely contributed to this effect. Similarly, a study by Hu et al. (36) that included a three-week AI course in the academic curriculum, featuring live didactic lectures and case studies from the literature, found that about half of the respondents felt their knowledge had somewhat improved, and one-third felt their knowledge had strongly improved. This aligns with our findings, indicating that well-structured AI courses can significantly enhance students' understanding. Our results are further corroborated by the study by Sabet et al. (37) which explored an AI school programme covering topics such as fuzzy systems, deep learning, image processing, electroencephalogram analysis, virtual reality, and text mining. In their study, post-test scores rose across all schools, showing statistically significant differences at a p-value of < 0.01. This is consistent with the statistically significant difference (p-value < 0.01) between the participants' mean pre-test and post-test scores in our study, suggesting that the course had a substantial effect on students' knowledge acquisition.

Additionally, introducing AI topics and principles in health professions education and undergraduate teaching was highly appreciated and echoed by the faculty involved in our study. They recognised the potential of AI to improve future care delivery and enhance performance. This perspective is congruent with Shinners et al. (38) who stated that healthcare professionals' pre-existing perceptions of AI can negatively impact technology use if they do not have a proper understanding of how it will enhance performance or improve care delivery.

This perspective is further supported by our study's findings, which revealed that the staff members who participated in teaching the course were in favour of repeating such courses in the future, emphasising the importance of AI in healthcare. This aligns with the opinions expressed by Blease et al. (39) where most experts in AI fields argued that medicine will be 'revolutionised' by innovations in machine learning.

The study investigated a novel topic in medical curricula using mixed methods design. However, one limitation of the study is that evaluation was limited to the first two levels of Kirkpatrick's model: reaction and learning, with no evaluation of the top levels of behaviour and results. Overreliance on lower levels of Kirkpatrick's model neglects behaviour and impact, which are significant long-term outcomes of training and education. It is recommended that future research should focus on changes in the participants' behaviour in the clinical environment as a result of the training programme, as well as on the impact represented in institutional outcomes that can be attributed to the training programme. Evaluation of higher levels provides more robust evidence than relying on participant perceptions gathered from surveys. Finally, evaluating students' learning was limited to domains of knowledge, including both low and high-cognitive skills.

CONCLUSION

Students showed a positive perception towards all aspects of the course, including its design, activities, materials and instructor availability. The course significantly improved their understanding of AI. Furthermore, the inclusion of AI topics and principles in health professions education and undergraduate teaching was highly valued and endorsed by the faculty. Based on the findings of this study, medical schools are encouraged to incorporate oundational AI education into undergraduate medical curricula through structured online learning.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Doaa Kamal (Associate Professor of Medical Education Faculty of Medicine, Suez Canal University, Ismailia, Egypt), Dr Iman Diab (Professor of Medical Biochemistry, Medical Education Department, Alexandria Faculty of Medicine, Alexandria, Egypt), Dr Nouran Nader, Dr Heba Khaled (demonstrator at medical education department, Alexandria Faculty of Medicine, Alexandria, Egypt), Dr Doaa Kamal (demonstrator at medical education department, Alexandria Faculty of Medicine, Alexandria, Egypt) and all study participants who generously gave their time to support this research.

ETHICAL APPROVAL

Ethical approval for the study was obtained from the Institutional Research Ethics Board (IREB) of the Faculty of Medicine, Alexandria University (Serial No: 0305995, IRB No: 00012098, FWA No: 00018699).

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APPENDIX A

Mapping Course Activities to COI Pillars Achieved

Days	Activities	Content/tasks	COI pillar achieved	Technology
Module 1: The Role of AI in the Medical Profession				
Day 1	Joining course on Moodle and WhatsApp group	Review of course schedule. Introduce oneself on WhatsApp official course group. Taking the Pretest.	Social presence Cognitive presence	Moodle Whatsapp Moodle
Day 2	Online videos	Watching three YouTube videos in preparation for synchronous workshop.	Cognitive presence	YouTube links on Moodle
Day 3	Online synchronous workshop	Course orientation mini lecture and interactive mini lectures. Facilitated discussions about basic definition of AI in healthcare, difference between human intelligence and AI, the advantages of using AI in medical practice, using AI in developing countries, and the role of the physician in the era of AI.	Teacher presence Cognitive presence	Zoom
Day 4–7	Group learning and research assignment	Students are allowed to self-enroll in debate groups either with or against using AI in healthcare. Groups are asked to collect scientific evidence about the point of view their group adopt (with or against AI). Group leader submits group points of debate with supportive references list.	Cognitive presence Social presence	Research engines Moodle
Day 8	Online videos Online reading	Debate process and dynamics. Debate assessment rubric.	Cognitive presence	YouTube videos Moodle
Day 8	Online synchronous debate session Online assignment	Group Debate about using AI in healthcare. Answer the reflection questions about debate process.	Cognitive teacher Social presence	Zoom Moodle
Module 2: Basics of AI Systems				
Day 9	Online audio recorded lecture	Basics of AI: history of development, types of AI.	Cognitive presence	Moodle
Day 10	Online quiz	Basics of AI.	Cognitive presence	Moodle
Module 3: Using AI for Patient Care				
Day 11	Online audio-recorded lecture	Role of AI in patient management and medical expert systems: Computer Aided Diagnosis (CAD), Computer Decision Support Systems (CDSS).	Cognitive presence	Moodle
Day 12	Online assignments	Final course test and course evaluation.	Cognitive presence	Moodle

APPENDIX B

Course Design and Delivery Practices Based on the Quality Standards of Online Courses

Standards/domains	Practices
1. General course information	A promo video was prepared to recruit students with basic course information including the course topics and structure, course design and the expected level of participation. An orientation online synchronous session was delivered on the second day of the AI course including: The course goals and objectives of every module were stated. The structure of the course was clearly explained, the course detailed structure of three modules with details of daily activities for each module and due dates for all activities. Screenshots of the online course structure and components were shown at the orientation lecture to help students find the various course components on the e-learning portal. However, the link was not clearly provided as students were supposed to be acquainted with the official platform of school. In addition, all instructions, schedule, rubrics and structure were available online at the official online course. Assignments and activities were clearly explained including purposes and etiquette expectations for online discussions, format of assignments needed (Word and JPG formats were required), and downloadable activities sheets were available. All online instructions and announcements were declared on the created course WhatsApp group and daily reminders for assignments submission were given. No prerequisite knowledge/technical skills or required competencies were stated. However, the course was offered to students early during clinical phase as basic patient-centred experiences were required to understand the role of AI in patient care and the details of AI systems structure used in diagnosis and treatment modalities. Both the course orientation module had a clear and current course schedule with topics, meeting times (if relevant), and activity or assignment, and due dates are posted. The expected dates for activities were clearly declared. In case of any changes, the course schedule was updated online with highlighted changes of expected dates and of the nature of activities. The course and institutional policies of plagiarism, pass/fail cut off point, and the expected level of participation were clearly stated at the orientation lecture. Assessment information and detailed instructions for assignments were available. Communication/activity tools (forums and assignments) were displayed on the course page. Tutors contacts were accessible through WhatsApp number and official school email. The expected dates for Instructor response and feedback were not stated, however feedback was given to students on daily basis for on time assignments. Resubmitted assignments had delayed feedback with no expected dates declared for feedback.

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Appendix B (*Continued*)

Standards/domains	Practices
	An online introduction or icebreaker activity for students and the instructor to develop an online community was performed on the first day of the course WhatsApp group (introduce themselves, hobbies and give a name to a robot WhatsApp emoji).
2. Course goals and learning outcomes	A detailed course description with clearly stated measurable objectives was designed. The course learning outcomes were described in terms of what the student will be able to achieve upon.
	Completion in multiple domains: (cognitive: knowledge, understanding, application, analysis, and evaluation), practical skills (technical and professional), and general transferable skills. other outcomes were added as research skills related learning outcomes (as the course project was transformed from clinical data collection and entry to research assignment).
	In every module, All The module/unit learning outcomes were clearly stated and are consistent with the course beginner's level outcomes. Instructions to students on how to participate to meet the learning outcomes are clearly stated.
	Learning outcomes are appropriately distributed among three modules and were tailored to be appropriate for the beginner's level.
3. Course materials	All Course content and materials were structured and provided under the relevant modules (figures 5, 6, and 7). Multiple resources were used including readings, PowerPoints, websites, videos, and activity sheets were used. Audio-recorded PowerPoints to facilitate delivery of knowledge objectives. All developed materials were checked for typos.
	Using equivalent alternatives to auditory and visual content was not applicable as there were no special needs students enrolled in the course.
4. Assessment	All the learning activities and assessments were consistent with the learning outcomes. For lower cognitive skills, online MCQ quizzes were used. In addition, for higher cognitive skills, two online workshop design discussion- based activities were implemented. Debate, research, and reflection assignments were used to assess the higher cognitive skills.
	The course grading policy with the weight of each assignment were clearly stated at the course orientation module and at each assignment description.
	Clear rubrics (specific and descriptive criteria and standards) were provided for the evaluation of students' debate grading and students were involved in judgement panel. However, guiding questions for facilitation of post-debate reflection assignment were provided but not a rubric.
	Each module had multiple variable assignments including research assignments, application assignments, quizzes, and discussion forums.
	The assessment strategies/tools selected are appropriate to the student work being assessed.
	A reflection assignment was included with an opportunity for Self-assessment of attitude towards using the AI in the medical profession and individualised feedback was provided.

(*Continued on next page*)

Appendix B (*Continued*)

Standards/domains	Practices
	Clear instructions are provided on how to submit assignments: downloadable activity sheets were provided, and formats were mentioned.
5. Learners' engagement	Students were involved in interactive learning activities including: instructor-student interactivity through online sessions and receiving feedback about assignments. content-student interactivity through audio-recorded lectures with notes taking. student-student interactivity through debate group assignment in module one during both research for supportive evidence and debate synchronous session.
	Learners are actively engaged in daily meaningful and relevant learning activities throughout the three course modules.
	A teacher's guide was developed including detailed instructor's plan for synchronous session response time, answers for frequently asked questions and feedback.
6. Course technology	The course used Moodle as the main platform for course implementation. The functions of Moodle that were used included: uploading reading materials and audio-recorded lectures, embedding links to YouTube videos, online assignments, and online quizzes. Zoom synchronous online tools, and WhatsApp social interaction tool were used. These tools were used to support the learning outcomes and enhance the learning process.
	All Instructions on how to access the online technologies and resources were introduced to students in the orientation face to face lecture on the first day of the course which was also available to students as an online resource (attached as a course deliverable as google drive link). In addition, detailed instructions were present on each online module description.
	The course activities were arranged logically in three modules and all activities were ordered sequentially according to the due dates.
	There were no synchronous online activities included in the course. In addition, using assistive technologies was not applicable as there were no students with disabilities enrolled in the course.
7. Learners' support	Instructions about seeking technical support at the IT unit and the location of the unit were provided verbally during the course orientation lecture, and through the course WhatsApp group. However, the official email of the IT unit was not added clearly to the course online instructions.
	Instructions about seeking academic support through course teaching assistants were provided, however no instructions of access to the institutions or the program's academic support systems instructions were added.
	Specific guidelines or links to resources on how to succeed as a student in online synchronous session were provided in course orientation. Detailed instructions for implementing all assignments, activities, and rubrics were added to each module.
	Guidance manual for teaching assistants on how to support learners in the course was developed.